

1 This invention relates to new nonwoven
2 unitary webs; more particularly to fibrous webs of
3 continuous synthetic textile filaments and to
4 methods of making the same. These textile fila-
5 ments are known man-made materials, being either
6 artificial or synthetic in nature as hereinafter
7 indicated, as distinct from natural fibers such as
8 cotton, wool, etc. For convenience herein they will
9 hereinafter be referred to as "synthetic filaments"
10 and/or "synthetic textile filaments".

11 As used herein the term "web" means a thin,
12 flimsy, fibrous sheet of indefinite length as dis-
13 tinguished from ribbons or batts which have con-
14 siderable thickness.

15 Heretofore, fibrous webs have been made
16 from staple length fibers and/or short paper-making
17 fibers, i.e., fibers less than about two inches in
18 length. Such webs are made by a card engine or by
19 paper-making or air-laying machines. These machines
20 produce a thin sheet or web of overlapping, inter-

1 secting, randomly arranged fibers. The web is held
2 together by the frictional entanglement of the
3 fibers and is quite weak.

4 Nonwoven fabrics are produced from these
5 prior art webs by plying a number of the webs to-
6 gether and applying an adhesive to the laminate to
7 bond the same into a unitary structure.

8 The present invention contemplates a
9 nonwoven unitary web of individual synthetic textile
10 filaments. Each filament in the web has an irregular
11 sinuosity throughout its length, thus presenting
12 looped fiber portions which overlap and frictionally
13 engage looped fiber portions of adjacent filaments
14 of the web. Each filament in a unit section of the
15 web has a length in its irregular sinuous form equal
16 to the length of the unit web section as measured
17 in the direction of filament lie, and each filament
18 of the unit section has a length in its stretched
19 or straightened condition substantially equal to the
20 corresponding length of its associated filaments
21 of the unit section in their straightened condition.

22 As a filament in a unit section, whether
23 the filament is in its sinuous form or in its
24 straightened condition, is of substantially the

1 same length as its adjacent filaments in the same
2 condition the resulting web is of substantially
3 uniform construction throughout its entire area.
4 The unitary web will have a substantially uniform
5 density and uniform "covering" properties, i.e.,
6 free of holes or thick areas.

7 Substantially all of the filaments lie in
8 the same general direction and the nonwoven unitary
9 webs of the invention have considerable strength in
10 the direction in which the filaments lie. Strong
11 nonwoven fabrics may be produced by plying a number
12 of these webs together, usually at angles to each
13 other, and adding a small amount of adhesive to hold
14 the plies together.

15 The fabrics produced from the webs of the
16 invention have strength and softness characteristics
17 which are not directly dependent on each other.

18 For example, the starting web for conven-
19 tional nonwoven fabrics is very soft and weak. Ad-
20hesive is applied to the web to hold the staple
21 length fibers together. Though the web develops
22 strength by the addition of adhesive it also becomes
23 harsher. Generally the more adhesive that is applied
24 the stronger the resultant fabric and also the harsh-
25 er the resultant fabric.

1 In contrast, if the webs of the invention
2 are used to produce a nonwoven fabric, adhesive is
3 applied to hold plies of webs together rather than
4 to hold fibers together. Strong fabrics may be pro-
5 duced with relatively small amounts of adhesive
6 which allows the final fabric to retain the excellent
7 softness of the webs of the invention.

8 The strength of the webs of the invention
9 is more dependent on the strength of the filaments
10 used and less dependent on the frictional entangle-
11 ment of filaments and the amount of adhesive applied.
12 This is in contrast to a web of staple length fibers
13 whose strength is less dependent on the strength of
14 the fiber used and more dependent on the frictional
15 entanglement of fibers and the amount of adhesive
16 applied.

17 The softness characteristics of fabrics
18 made from the webs of the invention are different than
19 the softness characteristics of prior art nonwoven
20 fabrics since the softness of the webs of the in-
21 vention is a result of filament surface whereas in
22 the prior art fabrics the softness is the result of
23 loose fiber ends, i.e., fiber ends which have not been
24 tied down by adhesive. The large surface area, free
25 of adhesive and fiber ends, gives the webs of the

1 invention a cool, smooth, silk-like softness and
2 makes the fabrics produced from these webs par-
3 ticularly suitable for use as surgical dressings,
4 absorbent dressings, sanitary napkin covers,
5 diapers, etc.

6 The present invention contemplates
7 methods for producing the nonwoven unitary webs of
8 the invention from a tow of continuous synthetic
9 filaments. Thus, for example, these webs may be
10 made by presenting a tow of continuous synthetic
11 filaments to a liquid flowing through a chamber;
12 any liquid which does not adversely affect the
13 filament may be used; suitable examples are water,
14 alcohol, etc. The tow and liquid move in the same
15 direction but the velocity of the tow is slower than
16 the velocity of the liquid. The flow of the liquid
17 is controlled to present diverging hydraulic forces
18 in the body of the liquid which open the tow and
19 spread it into a thin web of continuous filaments.
20 The thin web is presented to a condensing surface
21 and the filaments therein become condensed or com-
22 pacted lengthwise, in effect "shortened lengthwise"
23 so that each filament assumes an irregular sinuous
24 path. By effecting a substantially uniform length-
25 wise condensation of the filaments, the resulting

1 web is of substantially uniform construction through-
2 out its entire area. The resulting web is substan-
3 tially free of voids, thin areas and thick areas and
4 the filaments relatively uniformly cover the entire
5 surface. The sinuous filaments present looped por-
6 tions which overlap and entangle looped portions of
7 adjacent filaments.

8 In spreading the tow of continuous fila-
9 ments into a web the filaments must be maintained
10 under tension until the desired width of the web is
11 attained. The tension may be obtained by the appli-
12 cation of hydraulic forces to the tow as it is spread
13 into a web. The hydraulic forces must be strong
14 enough to part the slightly tangled filaments yet
15 gentle enough so that they do not form either open
16 places or conglomerations of filaments in the web.
17 After the tow is spread into a web, the web is placed
18 on a conveyor, moving at a relatively slower speed
19 than the web, and the tension the filaments are
20 under is thus released. This allows the filaments
21 to take the configuration imparted to them by the
22 differential in speed between the filaments and the
23 conveyor.

24 When the tension is released the filaments
25 fall in sinuous paths and form looped fiber portions

1 which overlap and entangle looped fiber portions of
2 adjacent filaments to form a nonwoven unitary web.
3 The length of each individual filament in its ir-
4 regular sinuous path is equal to the length of the
5 web formed.

6 The invention will be further described
7 in conjunction with the accompanying drawings,
8 wherein:

9 FIGURE 1 is a plan view of a nonwoven
10 unitary web of the present invention,

11 FIG. 2 is an enlarged cross-sectional
12 view taken along line 2-2 of FIG. 1,

13 FIG. 3 is a plan view of a fabric made
14 from a unitary web of this invention,

15 FIG. 4 is an enlarged cross-sectional
16 view taken along line 4-4 of FIG. 3,

17 FIG. 5 is a plan view of another fabric
18 made from a nonwoven unitary web of this invention,

19 FIG. 6 is a plan view of an apparatus
20 for carrying out certain steps in the method of
21 this invention,

22 FIG. 7 is a side elevation view of the
23 apparatus shown in FIG. 6,

24 FIG. 8 is a photomicrograph of a typical
25 nonwoven web of the present invention at an original

1 enlargement of approximately 20 to 1,

2 FIG. 9 is a photomicrograph of another
3 nonwoven web of the present invention at an
4 original enlargement of approximately 20 to 1,
5 and

6 FIG. 10 is a photomicrograph of still
7 another nonwoven web of the present invention at
8 an original enlargement of approximately 20 to 1.

9 Referring to the drawings, in FIG. 1
10 there is shown a nonwoven unitary web 21 of the
11 invention. The web comprises individual filaments
12 22 each of which lies in a sinuous path running in
13 the direction of the length of the web. Looped or
14 kinky portions of filaments overlap and entangle
15 looped or kinky portions of adjacent filaments.
16 Each individual filament in the web is at least as
17 long as the length of the web formed. The web is
18 very thin with the filaments 22 relatively uni-
19 formly distributed throughout the width of the web,
20 as indicated in FIG. 2.

21 In FIG. 3 there is shown a fabric 23 made
22 from two superposed webs of the invention. The
23 first web 24 contains individual filaments 25 whose
24 sinuous paths lie in the direction of the length of
25 the fabric produced. The length of each individual

1 filament in its sinuous path is equal to the length
2 of the web formed. A second web 26 containing in-
3 dividual filaments 27 lying in irregular sinuous
4 paths is plied with the above-mentioned web so that
5 the filaments in the second web run the width of
6 the fabric. The length of the filaments in this
7 web, in their sinuous paths, is approximately equal
8 to the width of the fabric. The two webs are held
9 together by a binder 28 applied in any desired manner,
10 suitably in a pattern of parallel lines running at
11 an angle of about 45° to the length of the fabric.

12 In FIG. 5 there is shown another fabric
13 29 made from a nonwoven unitary web 30 of the in-
14 vention and a superposed fibrous web 32 of randomly
15 arranged staple length fibers. In web 30 the con-
16 tinuous filaments 31 lie in sinuous paths running
17 in the direction of the length of the fabric. Each
18 filament 31 is at least as long as the length of
19 the fabric and presents looped portions which over-
20 lap and entangle looped portions of adjacent fila-
21 ments. The two webs are held together by an ad-
22 hesive binder 33 applied in any desired manner,
23 suitably in the form of a pattern of dots as shown.
24 The strength of this fabric is much greater in the
25 long direction than in the cross-direction and the

softness or "feel" is different on each side. The continuous filament side has a silk-like softness and the side containing the randomly arranged staple length fibers has a nap-like or flannel-like softness.

The webs of the invention may be produced from any of the known synthetic filaments, including artificial filaments. Suitable examples are viscose rayon, cuprammonium rayon, ethylcellulose, and cellulose acetate, nylon; polyesters, i.e. such as the product marketed under the trade mark "Dacron";
10 acrylics, i.e. such as the product marketed under the trade marks "Orlon", "Acrilan" and "Dynel"; polyolefins, i.e. polyethylene, polypropylene; polyvinylidene chloride, i.e. such as the product marketed under the trade mark "Saran"; polyvinyl chloride, polyurethanes, etc. These synthetic filaments may be used alone or in combination with one another.

The weight of the webs of the invention range from about 25 grains per square yard to 200 grains per square yard and preferably from about 35 grains per square yard to 100 grains per square yard.

20 The denier of the filaments used to produce the webs of the invention is in the range of from about 1 denier and somewhat less to about 10 denier. It is preferred that the filaments have

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1 a denier in the range of from about 1-1/2 to 6.
2 For example, viscose rayon filaments from about
3 1-1/2 to 3 denier have produced excellent results
4 in the production of the fabrics of the inven-
5 tion.

6 Filaments having a denier above the in-
7 dicated broad range are stiff and rigid and will
8 not lie in irregular sinuous paths uniformly
9 throughout the web. The fabrics produced from
10 webs of such high denier filaments are not drapeable
11 textile fabrics having a silk-like softness as con-
12 templated herein, but are rigid and harsh and un-
13 suitable for use in surgical dressings, sanitary
14 napkins and the like.

15 In the formation of the fabrics of the
16 present invention, as shown in FIGS. 6 and 7, a
17 bundel 40 of continuous filaments 41 having no
18 definite twist (called a tow) is continuously fed
19 by a pair of nip rolls 42 into the opening 43 of a
20 chamber 44 containing a flowing liquid. The tow
21 and liquid move in the same direction, but the
22 velocity of the tow is less than that of the liquid;
23 the drag of the liquid on the slower moving tow pulls
24 the tow through the chamber.

25 The cross-sectional shape of the chamber

1 is rectangular at the end at which the tow enters.
2 The sides of the chamber diverge from the entry
3 end to the discharge end while the top and the
4 bottom of the chamber converge from the entry end
5 to the discharge end, so that the rectangular shape
6 is widened and flattened to form a slot 45 at the
7 discharge end of the chamber. The divergence and
8 convergence of the walls are such that the area of
9 the chamber either remains substantially constant
10 along the length of the chamber, or decreases
11 slightly in the downstream direction.

12 The liquid enters the chamber at an open-
13 ing at the same end of the chamber at which the tow
14 enters, suitably as at 46. On entering the liquid
15 impinges on a baffle 47 so as to prevent any major
16 disruption of the tow. The liquid continually flows
17 through the chamber at a velocity greater than the
18 velocity at which the tow passes through the chamber
19 and thus maintains the tow under tension as it
20 passes through the chamber. As the tow enters the
21 chamber, the flowing liquid opens the tow and
22 separates the continuous filaments into a flat band.
23 The flat band is continually separated and widened
24 as it passes through the chamber to the discharge
25 end. The tow is separated by the shear stress

1 exerted by the liquid on the tow. This stress is
2 in the same direction as the liquid velocity and
3 where the walls and flow are divergent the stress
4 has a shear force component perpendicular to the
5 centerline of the chamber. This perpendicular
6 force component spreads the tow as it passes through
7 the chamber. At the discharge end of the chamber
8 the flat band is in the form of a web 48 of con-
9 tinuous filaments and this web is placed on a con-
10 tinuous wire screen 49.

11 The upper reach of the wire screen passes
12 from roller 50 closest to the chamber to roller 51
13 spaced away from the chamber and the lower reach
14 from roller 51 to roller 50. As the spread tow con-
15 tacta the screen, which is moving slower than the
16 tow, the tension is released. The individual fila-
17 ments fall in irregular sinuous paths on the screen,
18 forming looped portions in the individual filaments,
19 which overlap and entangle looped portions of ad-
20 jacent filaments.

21 The screen with the spread tow (web)
22 thereon passes over a suction box 52 to remove
23 liquid therefrom. The web and screen then pass to
24 a hot air drier 53 where the web of continuous fila-
25 ments is dried. The irregular sinuous paths of the

1 continuous filaments causes portions of filaments
2 to overlap and frictionally engage portions of ad-
3 jacent filaments to form a unitary web. The dried
4 unitary web 54 may then be laminated with card, air-
5 laid or other nonwoven fiber webs or with other
6 spread tow webs to produce a fabric in accordance
7 with the invention.

8 The liquid used is relatively unimportant
9 in the spreading of tow provided the liquid has no
10 adverse effects on the filaments. Economics, safety,
11 ease of handling, etc., make the use of water one
12 of the better liquids for the spreading of tow in
13 accordance with the invention.

14 The more important variables in the spread-
15 ing of tow of fine denier filaments according to the
16 method of the invention are: the type of liquid flow,
17 the condition of the layer of liquid at the diverg-
18 ing sides of the chamber and the relative speed of
19 the tow in the liquid.

20 The type of liquid flow in chamber 44 may
21 be either laminar or turbulent. This flow is con-
22 trolled primarily by the velocity of the liquid in
23 the chamber, and by the shape of the chamber.

24 The liquid layer at the sides of the
25 chamber has flow characteristics which do not ad-

1 versely affect the desired spreading of the tow.
2 At the most it has a minimum of turbulence, i.e.,
3 the formation of vortices or "eddy" currents at
4 the side walls are kept to a minimum. The con-
5 dition of the liquid layer at the side walls may
6 be controlled by maintaining the angle of diver-
7 gence of these walls at less than 10° or by placing
8 release ports or slits along the wall in order to
9 equalize liquid pressure throughout the chamber.

10 The liquid velocity in the chamber is
11 greater than the velocity of the tow as it passes
12 through the chamber to maintain the tow under ten-
13 sion and allow the action of the liquid to act on
14 the tow and spread it into web form. Satisfactory
15 results have been obtained with water velocities
16 in the range of from about 50 feet per minute to
17 500 feet per minute and somewhat higher. As the
18 liquid velocity is raised above the indicated range
19 the problems of preventing velocity fluctuations and
20 the formation of vortices at the walls of the chamber
21 increase. This can be minimized by decreasing the
22 cross-sectional area of the chamber, and thereby
23 increasing the velocity, in the downstream direction
24 to give a favorable pressure gradient, which en-
25 hances the stability of the flow and retards flow

1 separation.

2 Velocity fluctuations may also be re-
3 duced by making the distance between the converging
4 walls of the chamber as small as practical. The
5 width of the chamber at the downstream end should
6 be nearly the same as the desired width of the web.
7 The chamber depth at this location should be quite
8 small, on the order of one-sixteenth inch or less,
9 to give a uniform distribution of filaments across
10 the web.

11 Once the tow is spread into web form it
12 is presented to the slower moving condensing surface
13 of the wire screen. The differential in speed be-
14 tween the tow and the wire may be varied over wide
15 ranges to impart various irregular sinuous paths to
16 the filaments. This speed differential also governs
17 the amplitude of the sinuous path of individual
18 filaments in the web. Differentials in the speed
19 of the tow and the speed of the wire in the range of
20 from about 1.05 to 1 to 2 to 1 and even higher have
21 given satisfactory results.

22 By the method of the invention tows rang-
23 ing in diameter from 1/32 of an inch up to about 1
24 inch or more and containing from 5,000 to 60,000
25 filaments or more may be spread to thin flimsy webs

1 having weights ranging from about 25 grains per
2 square yard up to about 200 grains per square
3 yard or more.

4 In FIGS. 8, 9 and 10 there are shown
5 portions of typical nonwoven unitary webs produced
6 by spreading tows of continuous filaments. The
7 webs contain individual filaments which have an
8 irregular sinuosity and present looped fiber por-
9 tions which overlap and frictionally engage looped
10 fiber portions of adjacent filaments. The fila-
11 ments extend from one end of the web to the opposite
12 end and do not present fiber ends on the surface of
13 the fabric but, rather, present extended filament
14 surfaces which produce a cool, silk-like softness
15 in the web.

16 The degree of fiber looping of adjacent
17 filaments varies in FIGS. 8, 9 and 10 and is de-
18 pendent on the degree of condensing present when
19 the web of spread filaments is removed from the
20 spreading operation, i.e., the differential in
21 speed between the spread tow and the screen which
22 picks up the spread tow from the spreading liquid.
23 The fabric of FIG. 9 indicates the effect of the
24 lowest speed differential and that of FIG. 8 the
25 highest speed differential of the three figures.

1 The invention will be further illus-
2 trated in greater detail by the following specific
3 examples. The percentages indicated are by weight
4 unless specifically stated otherwise.

5 EXAMPLE 1

6 A viscose rayon tow approximately 3/32 of
7 an inch in diameter, 6,000 denier, and containing
8 2,934 individual continuous filaments of about 2
9 denier per filament is fed by a pair of nip rolls
10 into a spreading chamber at the rate of approximate-
11 ly 40.5 feet per minute. The spreading chamber is
12 28 $\frac{1}{2}$ inches long. The cross-sectional dimensions at
13 the entry end are 3/4 inch wide by 1/2 inch high and
14 at the discharge end are 6 inches wide by 1/16 inch
15 high. The cross-sectional area is substantially
16 constant over the entire length of the chamber. A
17 flow of water is maintained in the chamber through
18 a tube fastened to the bottom of the chamber near
19 the entry end as indicated in FIG. 7. A baffle is
20 used to deflect the water forward into the chamber
21 as it enters through this tube, again as indicated.
22 The water velocity through the chamber is approxi-
23 mately 395 feet per minute.

24 The tow passes through the entry hole into
25 the chamber and the flow of water pulls the tow

1 through the chamber. Divergent currents of water
2 cause the filaments to spread in a fan-shaped
3 pattern. The tow is removed from the discharge
4 end as a substantially uniform sheet of contin-
5 uous filaments 6 inches wide. These filaments are
6 discharged onto a wire screen passing over a suction
7 box. The screen is moving at $38\frac{1}{2}$ feet per minute.
8 The suction box removes the water from the contin-
9 uous filament sheet and the reduced speed of the
10 wire causes the individual filaments to lie in ir-
11 regular, sinuous paths and form looped portions which
12 overlap and entangle looped portions of adjacent
13 filaments.

14 The sheet on the screen is passed under a
15 spray of approximately 1% polyvinyl alcohol solution
16 and over a second suction box to remove more water
17 from the sheet. The sheet is then passed under a
18 hot air dryer to remove the remainder of the water
19 and the dry sheet rolled on a core. The nonwoven
20 unitary base web produced is approximately 6 inches
21 wide and weighs 56 grains per square yard.

22

EXAMPLE 2

23

A base web is made as outlined in Example

1 1 from 2-denier viscose rayon continuous filaments.
2 The web is approximately 6 inches wide and weighs
3 80 grains per square yard. This web is used to
4 form a fabric by angle laying two pieces of the web
5 between two other pieces of the web to form a four-
6 ply laminate. The filaments of the outer plies run
7 the length of the laminate while the filaments in
8 one of the inner plies lie at 60° measured clock-
9 wise from this length and the filaments in the other
10 inner ply lie at 60° measured counterclockwise from
11 this length.

12 The four-ply laminate is held together by
13 a viscose binder applied in a pattern of 6 lines per
14 inch with the lines running at an angle of 45° to
15 the length of the fabric. The final weight of the
16 fabric is 340 grains per square yard with 20 grains
17 per square yard of this being binder and 320 grains
18 per square yard being continuous filaments.

19 The strength of the fabric is determined
20 by taking a 1-inch by 6-inch sample and placing it
21 between the jaws of a conventional Constant-Rate-
22 of-Elongation tester, for example, the one sold by
23 the Inesco Corporation. The jaws of the machine are
24 4 inches apart and after the sample is clamped be-
25 tween the jaws, the jaws are separated at a rate of

1 4 inches per minute until the fabric breaks. When
2 the sample breaks, the tenacity of the fabric is
3 recorded. Five samples are tested with the 6-inch
4 length running in the machine direction of the
5 fabric, i.e., the length of the fabric, and five
6 samples are tested with the 6-inch length running
7 in the cross direction of the fabric, i.e., the
8 width of the fabric. The final strengths in the
9 machine- and cross-directions are then determined
10 by taking an average of the five samples.

11 The machine direction tenacity of the fab-
12 ric of this sample is determined to be 2.15 pounds
13 per inch per 100 grains per square yard and the
14 cross-direction tenacity is determined to be 1.66
15 pounds per inch per 100 grains per square yard.

16 The softness of this fabric is determined
17 by two different techniques, as follows:

18 The flexural rigidity (resistance) of the
19 fabric is determined by cutting an $8\frac{1}{2}$ -inch square
20 sample from the fabric and testing the same on a
21 Thwing-Albert Handle-O-Meter. In this instrument
22 a metal bar bends the fabric and the resistance to
23 flex is determined in milliamperes which is con-
24 verted to a "softness" figure in accordance with
25 known procedures. As this figure increases, the

1 softness or flexibility increases. The average
2 flexibility of this fabric as determined by this
3 machine is about 86.

4 A combination of the surface softness and
5 flexibility of the fabric is also determined by cut-
6 ting a 6-inch by 7-inch sample randomly from the
7 fabric. This sample is pushed down into a trumpet,
8 the large end of which is 2-5/8 inches in diameter
9 and the small end of which is 7/8 inch in diameter.
10 The sides of the trumpet curve inwardly toward the
11 center of the trumpet and have a radius of curvature
12 of 7/8 inch. The small end of the trumpet is inte-
13 gral with a cylinder 7/8 inch in diameter and 3-5/8
14 inches in length. The sample is pushed down into
15 the trumpet and through the cylinder by a vertical
16 probe. At the bottom of this probe is a spherical
17 ball 5/8 inch in diameter. The top of the probe is
18 attached to a cantilever weigh-bar system. The
19 motion of this weigh-bar is converted electronically
20 to an electric signal which is calibrated in terms
21 of grams of force exerted by the sample on the
22 probe. Hence, the final reading in grams of force
23 will decrease as the surface softness and flexibil-
24 ity increase. The surface softness and flexibility
25 of this sample, determined as described, is 10 grams

1 of force.

2

EXAMPLE 3

3 A second fabric is made by taking a con-
4 tinuous filament web as outlined in Example 1 and
5 angle-laying this between plies of normal card web.
6 The outer plies or card webs each weigh approximate-
7 ly 85 grains per square yard and are made from vis-
8 cose rayon fibers $1\frac{1}{2}$ -denier and 1-9/16 inches in
9 length. The two inner plies are made from the con-
10 tinuous filament web outlined in Example 1. One of
11 the inner plies lies at 60° measured clockwise from
12 the length of the final laminate, while the other
13 inner ply lies at 60° measured counterclockwise from
14 the length of the final laminate.

15 The 4-ply laminate is held together by a
16 viscose binder applied in a pattern of 12 diagonal
17 lines to the inch with the lines running at 20° to
18 the cross-direction of the fabric. The final fabric
19 weighs 302 grains per square yard with 20 grains
20 per square yard of this being binder, 112 grains
21 per square yard being continuous filament web and
22 170 grains per square yard being normal card web.

1 The strength of the fabric is determined
2 by the Constant-Rate-of-Elongation tester in the
3 same manner as outlined in Example 2. The machine
4 direction tenacity of this fabric is 1.21 pounds
5 per inch per 100 grains per square yard and the
6 cross-direction tenacity 2.07 pounds per inch per
7 100 grains per square yard.

8 The softness and/or the flexural rigidity
9 of this fabric is also determined by the two tech-
10 niques outlined in Example 2. The Handle-O-Meter
11 test evaluated the softness of this fabric at 91
12 while the trumpet test evaluated this fabric at
13 15 grams of force.

14 EXAMPLE 4

15 For comparative purposes comparable weight
16 nonwoven fabrics were made from all staple-length
17 fibers and the strength and softness of these fabrics
18 determined in the same manner as outlined in Examples
19 2 and 3.

20 The first of these all staple-length fab-
21 rics was made from 4 card webs each weighing approxi-
22 mately 70 grains per square yard and made from vis-
23 cose rayon fibers 1½-denier, 1-9/16 inches in length.

1 Two of the webs formed the outer plies of a 4-ply
2 laminate while the other two webs were angle-laid
3 between these outer plies with one ply running at
4 60° measured clockwise from the length of the fab-
5 ric and the other ply running at 60° measured
6 counterclockwise from the length of the fabric.
7 The 4-ply laminate was held together by a viscose
8 binder applied in a pattern of 6 lines per inch
9 with the lines running at 45° to the length of the
10 fabric. The total weight of the fabric was 300
11 grains per square yard, 20 grains of this being
12 binder and 280 grains of this being staple-length
13 fiber. The machine and cross-tenacities of this
14 fabric and the softness as determined by the Handle-
15 O-Meter and the trumpet test were determined in the
16 same manner as outlined in Examples 2 and 3 above and
17 are given in the following table.

18 The second all staple-length fiber nonwoven
19 fabric was made by laminating 4 plies of normal
20 oriented card web made from viscose rayon fibers
21 $1\frac{1}{2}$ -denier, 1-9/16 inches in length, with each ply
22 weighing approximately 80 grains per square yard
23 and with all of the plies running in the same direc-
24 tion, i.e., the machine direction of the final fabric.
25 The four plies were held together by a viscose binder

1 applied in a pattern of 6 lines per inch with the
2 lines running at 45° to the length of the fabric.
3 The final weight of the fabric was 340 grains per
4 square yard with 20 grains of this being binder
5 and 320 grains per square yard being staple-length
6 fiber.

7 Again, this fabric was tested for its
8 machine tenacity and its cross-tenacity and its
9 softness by both the Handle-O-Meter and the trumpet
10 test as outlined in Examples 2 and 3. These results
11 are also given in the following table.

	Fabric with outer plies staple length fiber webs and angle- laid inner plies of con- tinuous fila- ment webs Example 2	All staple length fiber fabric, inner plies angle- laid Example 3	All staple length fiber fabric, inner plies not angle- laid Example 4	All staple length fiber fabric, inner plies Example 4
Fabric weight (gr/yd ²)	340	302	300	340
Weight Binder (gr/yd ²)	20	20	20	20
Weight Continuous Filaments (gr/yd ²)	320	112	-	-
Weight Staple Length fiber (gr/yd ²)	-	170	280	320
Binder pattern (all viscose)	6-45° lines per inch	12-20° lines per inch	6-45° lines per inch	6-45° lines per inch
Machine direction tenacity (#/inch 100 gr/yd ²)	2.15	1.21	.91	1.19
Cross direction tenacity (#/inch, 100 gr/yd ²)	1.66	2.07	.27	.11
Softness by Handle-O- Meter Test	86	91	74	73
Softness by Funnel Test	10	15	25	26

1 The four examples of the above table
2 were of comparative weights. The amount of binder
3 applied in each instance was the same and the
4 manner in which the binder was applied was com-
5 parable in all cases. As can be seen from this
6 table the fabrics containing the continuous fila-
7 ment webs were both considerably stronger and con-
8 siderably softer than the fabrics made from all
9 staple-length fibers.

10 Although several specific examples of
11 the inventive concept have been described for
12 purposes of illustration, the invention should not
13 be construed as limited thereby nor to the specific
14 features mentioned therein except as the same may
15 be included in the claims appended hereto. It is
16 understood that changes, modifications and varia-
17 tions may be made in the fabric and the method here-
18 in described without departing from the spirit and
19 scope of the claimed invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:-

WHAT IS CLAIMED IS:

- 1 1. A nonwoven unitary web of individual
- 2 synthetic textile filaments each having an irregular
- 3 sinuosity throughout its length presenting looped
- 4 fiber portions which overlap and frictionally engage
- 5 looped fiber portions of adjacent filaments in the
- 6 web, said individual filaments in a unit section of
- 7 the web each having a length in its irregular sinuous
- 8 form substantially equal to the length of said unit
- 9 section in the direction of filament lie and a length
- 10 in its straightened condition substantially equal to
- 11 the corresponding length of its associated filaments
- 12 in their straightened condition, said web being of
- 13 substantially uniform construction throughout and
- 14 having substantially all of its filaments lying in
- 15 the same general direction.

2. A nonwoven unitary web of individual synthetic textile filaments of from about 1 to 10 denier and each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

3. A nonwoven unitary web of individual cellulosic filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

4. A nonwoven unitary web weighing from about 25 grains per square yard to 200 grains per square yard, of individual textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of

adjacent filaments in the web, said individual filaments in a unit section of the web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

5. A nonwoven unitary web of individual viscose rayon filaments of from about 1-1/2 to 6 denier each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

6. A nonwoven fabric comprising a plurality of fibrous webs at least one of which is a nonwoven unitary web of individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substanti-

ally equal to the corresponding length of its associated filaments in their straightened condition, said unitary web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

7. A nonwoven fabric comprising a plurality of fibrous webs and a bonding agent holding said webs together to form an integral fabric, at least one of said webs being a nonwoven unitary web of individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally entangle looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said unitary web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

8. A nonwoven fabric comprising a plurality of nonwoven unitary webs plied at angles to each other and said unitary webs comprising individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally entangle looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of a unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition,

said unitary web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

9. A nonwoven fabric comprising a plurality of fibrous webs at least one of said webs being of staple length fibers and at least one of said webs being a nonwoven unitary web of individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said unitary web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

10. A nonwoven fabric comprising two superposed fibrous webs, one of said webs being of staple length fibers and the other of said webs being a nonwoven unitary web of individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said unitary web being of substantially uniform

construction throughout and having substantially all of its filaments lying in the same general direction.

11. A nonwoven fabric comprising three superposed fibrous webs, the outer webs of said fabric being of staple length fibers and the inner web of said fabric being a nonwoven unitary web of individual synthetic textile filaments each having an irregular sinuosity throughout its length different than adjacent filaments and presenting looped fiber portions which overlap and frictionally engage looped fiber portions of adjacent filaments in the web, said individual filaments in a unit section of the unitary web each having a length in its irregular sinuous form substantially equal to the length of said unit section in the direction of filament lie and a length in its straightened condition substantially equal to the corresponding length of its associated filaments in their straightened condition, said unitary web being of substantially uniform construction throughout and having substantially all of its filaments lying in the same general direction.

12. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction that the liquid is moving, maintaining the tow under tension while in said liquid, and uniformly applying diverging hydraulic forces to said tow while under tension and being conveyed in said liquid whereby the tow is spread into a thin web of continuous filaments.

13. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction

that the liquid is moving and at a velocity slower than that of the liquid, and uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments.

14. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction that the liquid is moving, maintaining said tow under tension while in said liquid, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments and uniformly compacting said web in a lengthwise direction whereby the filaments assume irregular sinuous paths different than adjacent filaments and present looped portions which overlap and entangle looped portions of adjacent filaments to form a unitary web.

15. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction that the liquid is moving, maintaining said tow under tension while in said liquid, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments and presenting said web of continuous synthetic filaments to a surface moving away from said liquid and at a speed slower than the speed of said web in the liquid whereby a thin web of continuous synthetic filaments each having an irregular sinuosity different than adjacent filaments is formed.

16. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction that the liquid is moving, maintaining said tow under tension while in said liquid, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments and uniformly compacting said web in a lengthwise direction whereby the filaments assume irregular sinuous paths different than adjacent filaments and present looped portions which overlap and entangle looped portions of adjacent filaments to form a unitary web and drying said unitary web to remove the liquid.

17. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction that the liquid is moving, maintaining said tow under tension while in said liquid, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments and presenting said web of continuous synthetic filaments to a surface moving away from said liquid and at a speed slower than the speed of said web in the liquid whereby a thin web of continuous synthetic filaments each having an irregular sinuosity different than adjacent filaments is formed and drying said web to remove the liquid.

18. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to a liquid flowing through a chamber, conveying said tow in the liquid in the same direction

that the liquid is moving and at a velocity slower than that of the liquid, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in said liquid whereby the tow is spread into a thin web of continuous synthetic filaments and presenting said web of continuous synthetic filaments to a surface moving away from said liquid and at a speed slower than the speed of said web in the liquid whereby a thin web of continuous synthetic filaments each having an irregular sinuosity different than adjacent filaments is formed.

19. A method of producing a nonwoven unitary web of continuous synthetic filaments which comprises: presenting a tow of continuous synthetic filaments to water flowing through a chamber, conveying said tow in the water in the same direction that the water is moving, maintaining said tow under tension while in the water, uniformly applying diverging hydraulic forces to said tow while it is being conveyed in the water whereby the tow is spread into a thin web of continuous synthetic filaments and uniformly compacting said web in a lengthwise direction whereby the filaments assume irregular sinuous paths different than adjacent filaments and present looped portions which overlap and entangle looped portions of adjacent filaments to form a unitary web and drying said unitary web to remove the water.

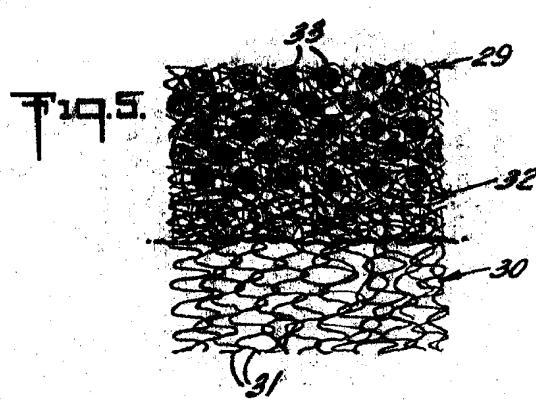
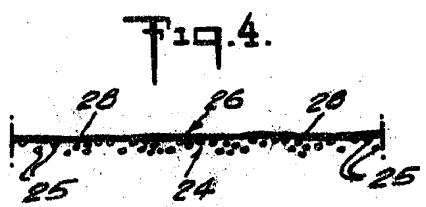
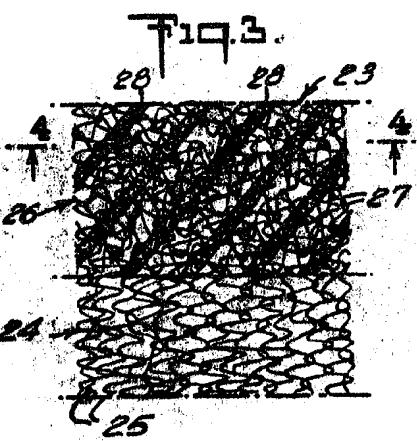
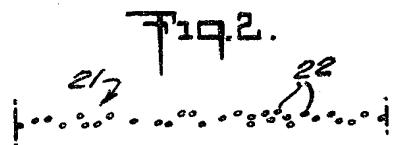
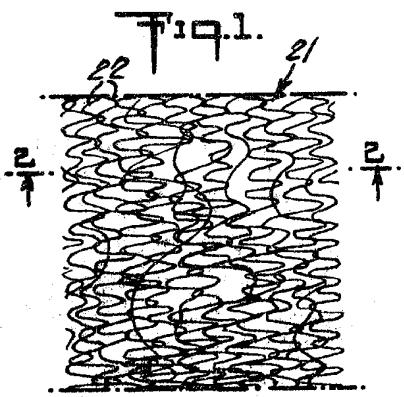
20. A web of filaments having an irregular sinuosity throughout its length presenting looped fiber portions, said individual filaments having a length substantially in the direction of filament lie, and a length substantially equal to the length of filaments when straightened, said web being of substantially uniform construction throughout and having its filaments in opposite directions.

21. A product of claim 20, wherein the web is made of a member selected from the group consisting of nylon, polyesters,

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polyacrylics, copolymers of vinylidene chloride and acrylonitrile, and mixtures of such monomers.

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Fig. 6.

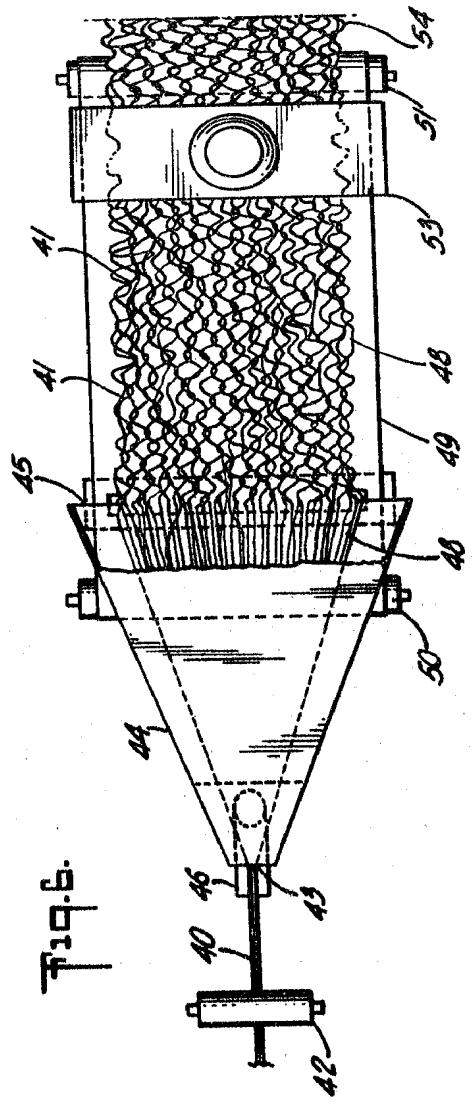
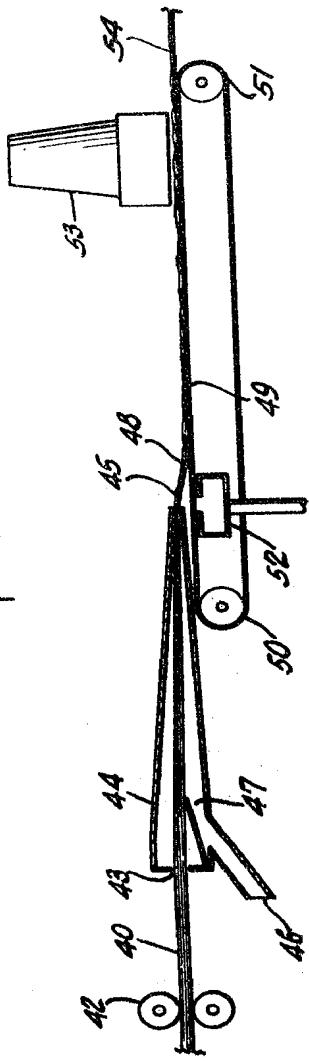


Fig. 7.



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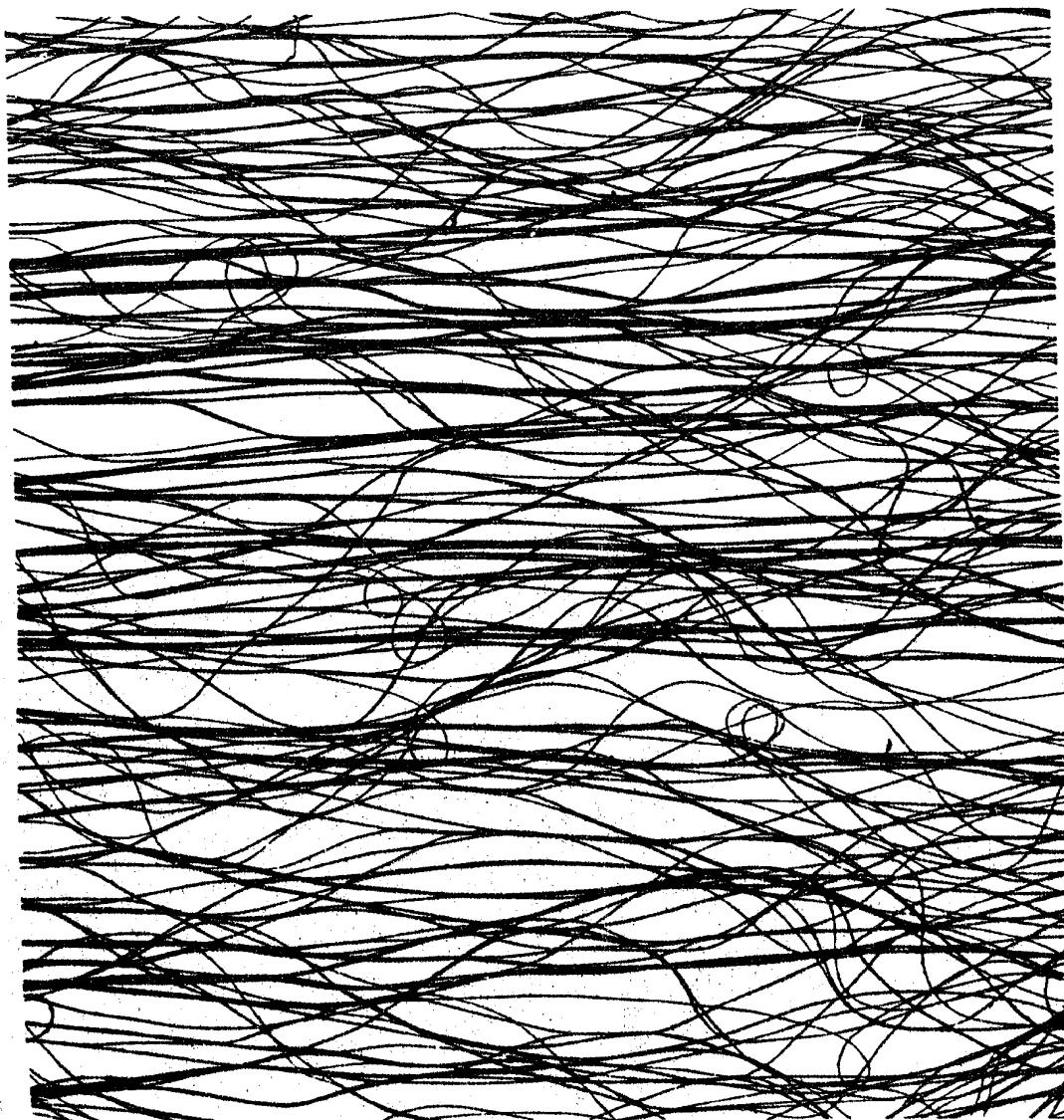
Fig. 8.



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Fig. 9.



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